Difference between the optical flickering colours of cataclysmic variables and symbiotic recurrent novae [*]

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We performed simultaneous observations in 3 bands (UBV) of the flickering variability of the recurrent novae RS Oph and T CrB at quiescence. Using new and published data, we compare the colours of the flickering in cataclysmic variables and symbiotic recurrent novae. We find a difference between the colours of the flickering source in these two types of accreting white dwarfs. The detected difference is highly significant with $p - value \approx 2 \times 10^{-6}$ for the distributions of $(U - B)_0$ colour and $p \approx 3 \times 10^{-5}$ on (U-B) versus (B-V) diagram.
The possible physical reasons are briefly discussed. The data are available upon request from the authors.

1 Introduction

Cataclysmic variables (CVs) are semi-detached interacting binary systems containing an accreting white dwarf primary and a mass-losing, late-type, near or on the main sequence secondary star that fills its Roche lobe. The accretion process can be either directly onto a strongly magnetic white dwarf or by way of an intervening accretion disc. The orbital periods for such systems are most commonly between $\sim$ 80 minutes and several hours (e.g. Warner 2003).

The *Recurrent Novae* (RNe) are previously recognized classical novae that repeat their outbursts. RNe are ordinary novae systems for which the recurrence time scale happens to be from a decade to a century. RNe are binary stars where matter accretes from a donor star onto the surface of a white dwarf, where the accumulated material will eventually start a thermonuclear explosion that makes the nova eruption (e.g. Anupama 2008; Schaefer 2010). The two RNe observed here (T CrB and RS Oph) belong to the group of the RNe with red giant companions and with very long periods comparable to one year, $P_{orb} = 227.6$ d for T CrB (Fekel et al. 2000) and $P_{orb} = 453.6$ d for RS Oph (Brandi et al. 2009). This type of nova is also referred to as a symbiotic recurrent nova, SyRN (e.g. Bode 2010, Shore et al. 2011). T CrB and RS Oph are also classified as symbiotic stars, because the mass donor is a red giant.

The flickering (stochastic light variations on timescales of a few minutes with amplitude of a few $\times 0.1$ magnitudes) is a variability observed in the three main types of binaries

that contain white dwarfs accreting material from a companion mass-donor star: cataclysmic variables (CVs), supersoft X-ray binaries, and symbiotic stars (Sokoloski 2003). Flickering is also visible in X-ray binaries and Active Galactic Nuclei at X-ray wavelengths (e.g. Uttley & McHardy 2001). Interestingly, the cataclysmic variable MV Lyr displays rms-flux relation, which is similar to that from accreting black holes (Scaringi et al. 2012).

The location of the flickering light source is supposed to be (1) at the outer edge of the accretion disk, where the gas stream from the secondary hits the disk (Warner & Nather 1971); (2) at the inner edge of the disc and the boundary layer between the disk and the central white dwarf (Bruch 2000); (3) inside the accretion disc itself (Baptista & Bortoletto 2004).

The first clues that the colours of the flickering depend on the type of the source can be found in Fig.6 of Zamanov et al. (2010a). Here we report new UBV observations of the flickering variability of RS Oph and T CrB and find statistically significant difference between the colour of the flickering of CVs and SyRNe.

2 Observational data

2.1 New observations

Our new observations are obtained by the 2.0 m RCC, the 60 cm and the 50/70 cm Schmidt telescopes of the Bulgarian National Astronomical Observatory Rozhen, located in the Rhodope mountain range. We also made use of the 60 cm telescope of the Belogradchik Astronomical Observatory, located in the vicinity of the Belogradchik Rocks. All the telescopes are equipped with CCD cameras. The 2.0 m RCC

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[*] Based on observations obtained at National Astronomical Observatory Rozhen and Belogradchik Observatory, Bulgaria

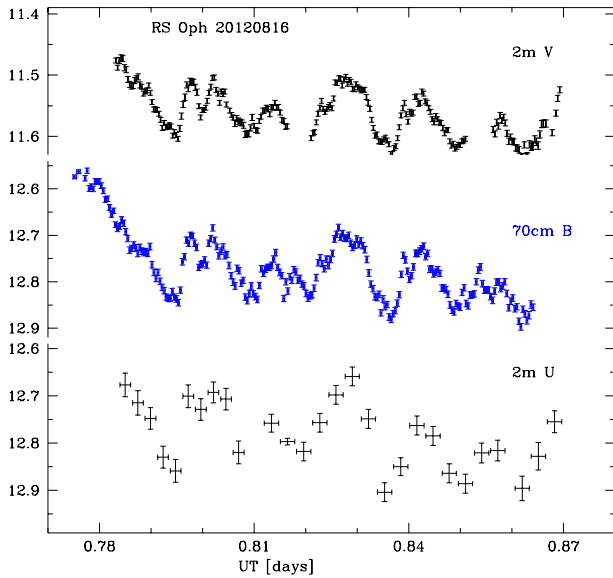[**] Corresponding author: e-mail: rkz@astro.bas.bg

Fig. 1 Flickering variability of RS Oph in the UBV bands on 2012 August 16.

telescope possesses a dual-channel focal reducer (Jockers et al. 2000) and observes simultaneously in two bands - U (blue channel) and V (red channel). The journal of observations is given in Table 1. The data are taken simultaneously using two or three telescopes. The only exception is the run 20120613, when the 60 cm Rozhen telescope observed in repeating U, B and V bands.

All the CCD images have been bias subtracted and flat fielded, and standard aperture photometry has been performed. The data reduction and aperture photometry are done with IRAF and have been checked with alternative software packages. For RS Oph and T CrB, the comparison stars of Henden & Munari (2006) have been used. An example of our observations is given in Fig.1.

2.2 Data from literature

Bruch (1992) measured the colours of the flickering light source of 12 CVs (RX And, AE Aqr, V603 Aql, BV Cen, WW Cet, SS Cyg, HR Del, AH Her, EX Hya, WX Hyi, V426 Oph, GK Per) and two RNe (RS Oph and T CrB). His data included 36 measurements of $(B-V)_0$ and 20 of $(U-B)_0$ colour.

Additionally we also made use of our own partly published observations of four CVs: V425 Cas (Tsvetkova et al. 2010), MV Lyr (Boeva et al. 2011), V794 Aql (Latev et al. 2011), KR Aur (Boeva et al. 2012) and of two SyRNe: RS Oph (Zamanov et al. 2010a) and T CrB (Zamanov et al. 2010b),

3 Differences between SyRNe and CVs

3.1 Colours of the flickering source

To calculate the colours of the flickering light source we follow Bruch (1992). In this method is considered that the flickering source is 100% modulated and that all the variability during each night is due to flickering. Following the Bruch's (1992) method we calculate the flux of the flickering light source for each band, using our UBV observations and Bessel (1979) calibration for the fluxes of a zero-magnitude star. After that we transform the fluxes into magnitudes, correct them for the interstellar extinction, and calculate $(U-B)_0$ and $(B-V)_0$ colours of the flickering source. The flickering colours are computed on a timescale of ≈ 1 hour. Because usually the different bands do not start or end at the same time, we cut them (before the calculations) to the same time interval. This is done for the new data and for our published observations as well.

We use the reddening law from Fitzpatrick (1999). We adopt reddening $E(B-V) = 0.0 \pm 0.05$ for MV Lyr, $E(B-V) = 0.05 \pm 0.05$ for KR Aur (Verbunt 1987), $E(B-V) = 0.2$ for V794 Aql (Godon et al. 2007), $E(B-V) = 0.73 \pm 0.06$ for RS Oph (Snijders 1987), and $E(B-V) = 0.14 \pm 0.05$ for T CrB (Parimucha & Vaňko 2006).

The results are presented in Table 2, where the first column gives the date of observation in format YYYYM-MDD, the second – minimum and maximum B band magnitude during the observation, the third and the fourth – the $(B-V)_0$ and $(U-B)_0$ colours of the flickering sources, corrected for the interstellar extinction with the corresponding errors. The errors are evaluated from the accuracy of the photometry. They depend on the brightness of the object, and also on the flickering amplitude (e.g. if the amplitude of the flickering is large, we obtain good flickering colours even if the object is with lower brightness).

3.2 Difference in $(U-B)_0$ colours

Fig. 2 shows the histograms for $(U-B)_0$ colours of the flickering light sources of CVs (solid line) and SyRNe (dashed line). The Kolmogorov-Smirnov test compares the cumulative distributions of two data sets ($N_1 = 26$, $N_2 = 16$). The test gives maximum difference between the cumulative distributions $D = 0.80$ and a probability of $p = 2.1 \times 10^{-6}$ that the two data sets are drawn from the same parent population.

The Wilcoxon-Mann-Whitney U-Test checks the hypothesis whether two sample populations have the same median of distribution. It gives $p = 4.8 \times 10^{-7}$. This value is better than that produced by the Kolmogorov-Smirnov test and confirms the result. The values of $p << 10^{-3}$ indicate that there is highly significant difference in $(U-B)_0$ colour of the flickering between SyRNe and CVs.
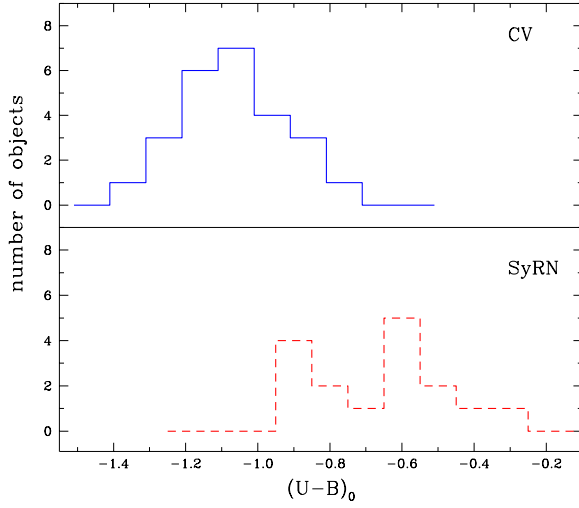
Fig. 2 Histograms showing the distribution of $(U - B)_0$ colour of the flickering source of CVs (blue solid line) and SyRNe (red dashed).
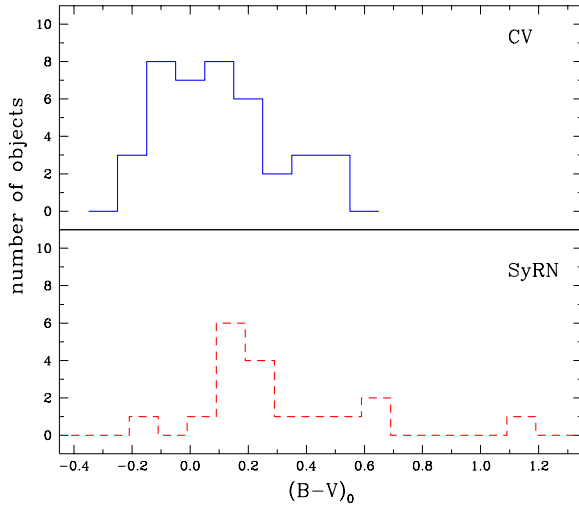

Fig. 3 Histograms showing the distribution of $(B - V)_0$ colour of the flickering source of CVs (blue solid line) and SyRNe (red dashed).

3.3 $(B - V)_0$ colour

Fig. 4 shows the histograms for $(B - V)_0$ colours of the flickering light sources of CVs (solid line) and SyRNe (dashed line). The Kolmogorov-Smirnov test on the histograms in Fig. 3 ($N_1 = 40$ and $N_2 = 18$) gives a probability $p = 0.006$ (Kolmogorov-Smirnov statistic $D = 0.46$). The Wilcoxon-Mann-Whitney U-Test for $(B - V)_0$ gives $p = 3 \times 10^{-3}$.

Both tests point to a statistically significant difference in the $(B - V)_0$ colours at a level of 0.01. This value is not as high as that in Sect. 3.2 and indicates that the difference between CVs and SyRN is considerably more pronounced in the $(U - B)_0$ colour, than in $(B - V)_0$.
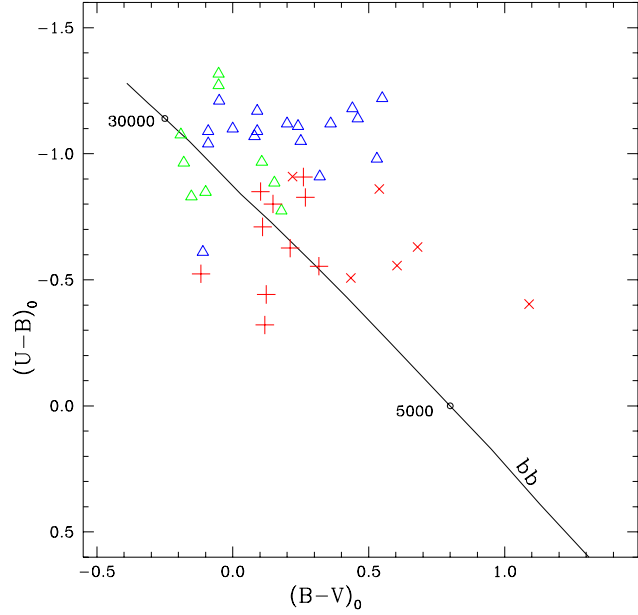

Fig. 4 Positions of the flickering light source on a $(U - B)$ vs $(B - V)$ diagram. The solid line represents the blackbody. RS Oph is marked with (red) plus symbols, T CrB – with (red) crosses. The blue (Bruch 1992) and green (our data from Table 2) triangles are the CVs.

3.4 Two-colour diagram

Fig. 4 represents a two-colour diagram, $(U - B)_0$ versus $(B - V)_0$ for the flickering light source in a number of CVs and SyRNe. In this figure, the cataclysmic variables are given with triangles: 17 blue triangles denote the data taken from Bruch (1992) and 9 green triangles represent our measurements (Table 2). RS Oph is represented by 10 red plus symbols – 1 data point from Bruch (1992) and 9 are our measurements. T CrB is represented by 6 red crosses, 2 of them are from Bruch (1992) and 4 are our observations. The solid line represents the blackbody radiation.

The two samples, CVs and SyRNe, have $N_1 = 26$ and $N_2 = 16$ data points, respectively. Even by eye it is visible that the two distributions occupy different regions on this diagram.

Using the data in Fig.4, we compare colours of the flickering of the SyRNe with those of the CVs, by a two-dimensional Kolmogorov-Smirnov test (Peacock 1983; Fasano & Franceschini 1987). The test gives a probability of 3×10^{-5} that both distributions are extracted from the same parent population. This is a highly significant value, which indicates that in this diagram there are statistically significant differences between the flickering of these two classes of accreting white dwarfs.

4 Discussion

The results of the statistical tests in Sect.3 confirm with higher level of significance ($p \sim 10^{-6}$) our early findings

$(p \sim 2 \cdot 10^{-3})$ based on a smaller amount of data (Zamanov et al. 2010a). We performed experiments to use different values of $E(B - V)$ and the interstellar extinction law (e.g. Cardelli, Clayton & Mathis 1989, and other possibilities included in NASA/IPAC extinction calculators). They change the $p - values$ by less than 50%. We conclude that the two SyRNe have indeed different colours of the flickering in comparison with the CVs.

4.1 Parameters of the binary systems

There are a few important differences between the classical CVs and the SyRNe, which could be the reason for the detected differences (Sect. 3) in the colours of the flickering sources:

1. the orbital periods of CVs are less than one day, while for the SyRNe they are longer than 100 d.

2. in CVs mass accretion rates are $\dot{M}_{acc} \sim 1 \times 10^{-10} - 7 \times 10^{-9}$ M$_{\odot}$ yr^{-1} (Echevarría 1994). The SyRNe accrete at higher rates: T CrB at $\dot{M}_{acc} \approx 2.3 \times 10^{-8}$ M$_{\odot}$ yr^{-1} (Selvelli, Cassatella & Gilmozzi 1992), RS Oph at $\dot{M}_{acc} \approx 2 \times 10^{-8}$ M$_{\odot}$ yr^{-1} (Nelson et al. 2011).

3. in the CVs, the average value of the white dwarf mass is $M_{WD} = 0.83 \pm 0.23$ M$_{\odot}$, and generally $M_{WD} \leq 1.1$ M$_{\odot}$ (Zorotovic, Schreiber, & Gänsicke 2011; Savoury et al. 2011). The masses of the white dwarfs in SyRNe are close to the Chandrasekhar limit $M_{WD} = 1.37 \pm 0.13$ M$_{\odot}$ in T CrB (Stanishev et al. 2004, Mukai et al. 2013), $M_{WD} = 1.2 - 1.4$ M$_{\odot}$ in RS Oph (Brandi et al. 2009).

4. As a consequence of 3., the white dwarf radius in RNe is expected to be smaller. Using Eggleton's mass-radius relation as quoted by Verbunt & Rappaport (1988), we estimate that in T CrB and RS Oph, the white dwarf radius should be smaller by a factor of 2. This could play an important role if the flickering is connected with the boundary layer between the accretion disk and the white dwarf (see Bruch & Duschl 1993).

It is worth noting that (i) the mass donors in SyRNe are red giants rather than main-sequence stars in CVs. Although the temperatures of both are comparable, the contribution of the red giants to the quiet light in the optical bands could be larger. However this will not affect our results, because the method applied here uses only the variable part of the light curve; (ii) the optical flux in most symbiotic stars is affected by light from the red giant, which does not change on short time-scales (see also Sect 6.2 in Sokoloski, Bildsten & Ho 2001).

4.2 Models of the flickering

Yonehara, Mineshige & Welsh (1997) proposed a model in which light fluctuations are produced by occasional flare-like events and subsequent avalanche flow in the accretion disk atmospheres. Ribeiro & Diaz (2006) simulated the flickering as a set of discrete flares on the accretion disk. Each flare is generated at a random position inside a pre-defined region. In these models the detected difference in

the colours of the flickering should be associated with the temperature and distribution of the flare-like events.

Dobrotka et al. (2010) proposed that the aperiodic variability is produced by turbulent elements in the disc. In this model the detected distinction in Fig.4, could be due to a difference in the temperatures of the material in the turbulent elements as a result of the higher mass transfer rate and larger accretion disks in the SyRNe.

Scaringi (2014) developed a physical model for the flickering variability in CVs. Many statistical properties of the flickering are explained with the fluctuating accretion disc model. In this model the detected difference could be connected to the manner in which the disk is fluctuating at higher and lower mass accretion rates.

In the CVs, the ultraviolet line diagnostics demonstrates that the accretion disk losses mass in the form of accretion disk winds (e.g. Vitello & Shlosman 1993), while in T CrB and RS Oph the opposite process (accretion from stellar wind) plays an important role in the accretion. The stellar wind capture contributes about 20% to the total mass transfer rate in T CrB (Selvelli et al. 1992), and is also important in RS Oph (Wynn 2008). The presence/non-presence of disk wind could change the properties of flares and fluctuations.

4.3 Place of the flickering

In CVs the average $(U - B)_0$ colour of the flickering corresponds to a blackbody temperature ~ 20000 K, and the average $(B - V)_0$ to ~ 10000 K. In SyRNe both colours give a temperature ~ 9000 K.

The radial temperature profile of a steady-state accretion disk is:

$$T_{eff}^4 = \frac{3G\dot{M}_{acc}M_{WD}}{8\pi\sigma R^3}\left[1 - \left(\frac{R_{WD}}{R}\right)^{1/2}\right], \qquad (1)$$

where G is the gravitational constant, σ is the Stefan-Boltzmann constant, R_{WD} is the white dwarf radius, R is the radial distance from the white dwarf. Using the parameters for SyRNe, a temperature ~ 9000 K should be achieved at a distance $R \sim 0.5$ $R_{\odot}$ from the white dwarf, which corresponds to ~ 120 R_{WD}. For the CVs the colours give a location of the flickering at $R \sim 0.08 - 0.20$ $R_{\odot}$ from the white dwarf, which corresponds to $8 - 20$ R_{WD}. Perhaps in CVs, as a result of lower mass accretion rate and lower white dwarf mass, the flares and/or fluctuations (see Sect.4.2) are ignited closer to the white dwarf in comparison with SyRNe, which results in different colours of the flickering.

5 Conclusions

We find a statistically highly-significant difference between the colours of the flickering source in cataclysmic variables and symbiotic recurrent novae. This difference is likely to be connected with the mass accretion rate and white dwarf mass and should be useful to test the theoretical models of flickering.

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Table 2 Colours of the flickering light source, corrected for interstellar extinction.

object date	$(B-V)_0$	$(U-B)_0$
RS Oph		
20080706	$+0.123\pm0.06$	-0.442 ± 0.05
20090721	$+0.317\pm0.04$	-0.554 ± 0.05
20090723	$+0.102\pm0.06$	-0.850 ± 0.15
20120427	$+0.148\pm0.05$	-0.801 ± 0.04
20120613	$+0.211\pm0.06$	-0.626 ± 0.08
20120815	$+0.260\pm0.04$	-0.908 ± 0.04
20120816	-0.117 ± 0.07	-0.524 ± 0.16
20130812	$+0.267\pm0.04$	-0.827 ± 0.05
20130813	$+0.118\pm0.15$	-0.321 ± 0.15
T CrB		
20090120	$+0.434\pm0.13$	-0.507 ± 0.05
20090227	$+0.604\pm0.20$	-0.556 ± 0.06
20100430	$+0.539\pm0.30$	-0.860 ± 0.15
20110211	$+1.090\pm0.35$	-0.644 ± 0.14
KR Aur		
20090120	-0.052 ± 0.07	-1.272 ± 0.08
20090226	-0.052 ± 0.11	-1.324 ± 0.18
20101231	$+0.179\pm0.04$	-0.774 ± 0.08
MV Lyr		
20090722	$+0.107\pm0.04$	-0.968 ± 0.08
20100815	-0.100 ± 0.07	-0.848 ± 0.15
V794 Aql		
20090724	$+0.153\pm0.04$	-0.885 ± 0.07
20100813	-0.152 ± 0.05	-0.830 ± 0.09
V425 Cas		
20090120	-0.191 ± 0.12	-1.076 ± 0.14
20090723	-0.180 ± 0.17	-0.965 ± 0.18

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Table 1   CCD observations of flickering. The following are given in the table: date, UT start and UT end of the run, the telescope, band, exposure time, number of CCD images, average magnitude in the corresponding band, minimum-maximum magnitudes in each band, standard deviation of the mean and typical observational error.

date	UT start-end	telescope	band	exp-time (s)	N_{pts}	Average (mag)	Min.– Max. (mag)-(mag)	St. dev. (mag)	Error (mag)
RS Oph									
2008 Jul 06[a]	19:46-21:28	2.0 m Roz	U	300	16	12.546	12.450 - 12.721	0.074	0.011
		50/70 cm Sch	B	20,60,100	48	12.471	12.380 - 12.615	0.052	0.005
		2.0 m Roz	V	30	160	11.232	11.160 - 11.333	0.037	0.007
2009 Jul 21[a]	20:57-21:33	50/70 cm Sch	U	120	16	12.016	11.863 - 12.166	0.098	0.013
		60 cm Roz	B	40	29	12.114	11.991 - 12.277	0.070	0.007
		60 cm Bel	V	30	39	11.069	10.895 - 11.236	0.081	0.004
2009 Jul 23[a]	20:52-21:30	2.0 m Roz	U	120	10	11.719	11.606 - 11.845	0.082	0.028
		50/70 cm Sch	B	30	38	11.979	11.857 - 12.099	0.067	0.007
		2.0 m Roz	V	10	100	10.978	10.863 - 11.082	0.064	0.008
2012 Apr 27[b]	00:28-01:34	50/70 cm Sch	U	60,120	35	12.050	11.850 - 12.244	0.091	0.011
		60 cm Roz	B	60	53	12.112	11.934 - 12.271	0.074	0.006
		60 cm Bel	V	20	97	10.992	10.882 - 11.120	0.053	0.006
2012 Jun 13[b]	21:45-23:38	60 cm Roz	U	120	34	12.599	12.407 - 12.762	0.089	0.014
		60 cm Roz	B	20	34	12.531	12.380 - 12.671	0.086	0.012
		60 cm Roz	V	10	34	11.376	11.274 - 11.492	0.063	0.007
2012 Aug 15[b]	18:44-20:30	2.0 m Roz	U	90	55	13.089	12.659 - 13.538	0.303	0.019
		60 cm Roz	B	60	65	12.949	12.624 - 13.208	0.211	0.009
		2.0 m Roz	V	10	53	11.704	11.453 - 11.908	0.157	0.008
2012 Aug 16[b]	18:48-20:48	2.0 m Roz	U	180,240	26	12.783	12.659 - 12.904	0.071	0.022
		50/70 cm Sch	B	30	217	12.775	12.584 - 12.897	0.064	0.007
		2.0 m Roz	V	10	217	11.563	11.472 - 11.633	0.038	0.008
2013 Aug 12[b]	19:09-21:30	2.0 m Roz	U	180	34	11.996	11.766 - 12.171	0.121	0.009
		50/70 cm Sch	B	20	412	12.121	11.916 - 12.270	0.085	0.012
		2.0 m Roz	V	3,5	335	11.060	10.897 - 11.203	0.070	0.005
2013 Aug 13[b]	20:40-21:22	2.0 m Roz	U	180	11	12.580	12.522 - 12.645	0.044	0.011
		50/70 cm Sch	B	15,20	84	12.579	12.476 - 12.659	0.042	0.010
		2.0 m Roz	V	3	118	11.441	11.378 - 11.503	0.028	0.004
T CrB									
2009 Jan 20[a]	02:27-04:07	2.0 m Roz	U	180	28	11.747	11.517 - 11.921	0.118	0.025
		50/70 cm Sch	B	10	240	11.199	11.108 - 11.269	0.035	0.011
		2.0 m Roz	V	5	559	9.916	9.878 - 9.952	0.015	0.009
2009 Feb 27[a]	00:15-01:40	2.0 m Roz	U	180	24	12.330	12.162 - 12.465	0.089	0.028
		50/70 cm Sch	B	40	24	11.482	11.438 - 11.521	0.021	0.005
		2.0 m Roz	V	7	490	10.168	10.138 - 10.191	0.009	0.007
2010 Apr 30[b]	18:46-20:25	60 cm Roz	U	120	27	12.003	11.765 - 12.196	0.115	0.006
		60 cm Roz	B	30	30	11.405	11.339 - 11.457	0.027	0.007
2010 Apr 30[b]	20:30-22:10	60 cm Roz	B	30	110	11.410	11.350 - 11.469	0.027	0.012
		60 cm Roz	V	10	109	10.042	9.992 - 10.073	0.015	0.008
2011 Feb 11[b]	01:04-03:44	50/70 cm Sch	U	120	86	12.790	12.686 - 12.857	0.037	0.006
		60 cm Roz	B	40	121	11.801	11.781 - 11.817	0.007	0.004
		60 cm Roz	V	20	121	10.343	10.330 - 10.356	0.006	0.003
KR Aur									
2009 Jan 20[a]	19:06-22:21	2.0 m Roz	U	300	25	17.227	16.310 - 17.730	0.417	0.050
		50/70 cm Sch	B	300	28	18.342	17.510 - 18.780	0.366	0.035
		2.0 m Roz	V	300	27	18.342	17.510 - 18.780	0.366	0.030
2009 Feb 26[a]	17:36-23:34	2.0 m Roz	U	300	49	17.706	17.110 - 17.930	0.196	0.050
		50/70 cm Sch	B	300	20	18.720	17.210 - 18.890	0.073	0.025
		2.0 m Roz	V	300	53	18.720	17.210 - 18.890	0.073	0.020
2010 Dec 31[b]	17:59-20:03	2.0 m Roz	U	300	22	13.241	13.080 - 13.410	0.124	0.030
		50/70 cm Sch	B	60	117	14.262	14.032 - 14.487	0.124	0.020
		2.0 m Roz	V	30	237	14.082	13.853 - 14.319	0.111	0.010

Table 1   Continuation.

date	UT start-end	telescope	band	exp-time (s)	N_{pts}	Average (mag)	Min.- Max. (mag)-(mag)	St. dev. (mag)	Error (mag)
MV Lyr									
2009 Jul 22[a]	20:04-21:27	2.0 m Roz	U	120	30	12.796	12.580 - 12.916	0.089	0.031
		50/70 cm Sch	B	60	73	13.702	13.502 - 13.805	0.083	0.007
		2.0 m Roz	V	30	144	13.657	13.479 - 13.777	0.073	0.005
2010 Aug 15[a]	22:37-23:59	50/70 cm Sch	U	180	27	12.135	12.000 - 12.221	0.062	0.020
		60 cm Roz	B	120	25	12.946	12.810 - 13.029	0.054	0.030
		60 cm Bel	V	30,40,60	62	12.912	12.767 - 12.985	0.050	0.005
V794 Aql									
2009 Jul 23[a]	00:16-01:18	2.0 m Roz	U	240	13	15.264	15.129 - 15.458	0.089	0.060
		50/70 cm Sch	B	180	20	16.283	16.160 - 16.542	0.102	0.060
		2.0 m Roz	V	60	53	15.992	15.835 - 16.270	0.099	0.020
2010 Aug 13[a]	19:43-21:26	2.0 m Roz	U	300	18	14.580	14.450 - 14.723	0.092	0.016
		50/70 cm Sch	B	180	32	15.357	15.226 - 15.514	0.078	0.012
		2.0 m Roz	V	90	83	15.055	14.941 - 15.178	0.067	0.007
V425 Cas									
2009 Jan 20[a]	17:01-18:37	2.0 m Roz	U	20	25	14.823	14.680 - 14.980	0.070	0.013
		50/70 cm Sch	B	20	44	15.516	15.370 - 15.650	0.062	0.020
		2.0 m Roz	V	20	55	15.343	15.220 - 15.470	0.055	0.020
2009 Jul 23[a]	00:20-01:30	2.0 m Roz	U	180	18	14.084	13.953 - 14.228	0.082	0.006
		50/70 cm Sch	B	180	32	14.934	14.781 - 15.094	0.086	0.010
		2.0 m Roz	V	60	62	14.719	14.549 - 14.866	0.080	0.010

[a] partly published observations, see Sect.2.2 for references.
[b] new data